PROCEEDINGS

OF

THE ROYAL SOCIETY.

1838. No. 32.

February 15, 1838.

DAVIES GILBERT, Esq., Vice-President, in the Chair.

A paper was in part read, entitled "Experimental Researches in Electricity," Twelfth Series, by Michael Faraday, Esq., D.C.L., F.R.S., &c.

February 22, 1838.

FRANCIS BAILY, Esq., V.P. and Treas., in the Chair.

William Thomas Denison, Esq., R.E., and Joseph Locke, Esq., were elected Fellows of the Society.

The reading of a paper, entitled, "Experimental Researches in Electricity," Twelfth Series, by M. Faraday, Esq., D.C.L., F.R.S., was resumed.

March 1, 1838.

The Right Honourable the EARL of BURLINGTON, Vice-President, in the Chair.

Alexander Wilson, Esq., was elected a Fellow of the Society.

The reading of a paper, entitled "Experimental Researches in Electricity," Twelfth Series, by Michael Faraday, Esq., D.C.L., F.R.S., &c., was resumed and concluded.

Experimental Researches in Electricity: Twelfth Series. By Michael Faraday, Esq., D.C.L., F.R.S., Fullerian Professor of Physiology in the Royal Institution of Great Britain.

The object of the present series of researches is to examine how far the principal general facts in electricity are explicable on the theory adopted by the author, and detailed in his last memoir, relative to the nature of inductive action. The operation of a body charged with electricity, of either the positive or negative kind, on other bodies in its vicinity, as long as it retains the whole of its charge, may be regarded as *simple induction,* in contradistinction to the effects which follow the destruction of this statical equilibrium, and imply a transit of the electrical forces from the charged body to

those at a distance, and which comprehend the phenomena of the *electric discharge*. Having considered, in the preceding paper, the process by which the former condition is established, and which consists in the successive polarization of series of contiguous particles of the interposed insulating dielectric; the author here proceeds to trace the process, which, taking place consequently on simple induction, terminates in that sudden, and often violent interchange of electric forces constituting *disruption*, or the electric discharge. He investigates, by the application of his theory, the gradual steps of transition which may be traced between perfect insulation on the one hand, and perfect conduction on the other, derived from the varied degrees of specific electric relations subsisting among the particular substances interposed in the circuit: and from this train of reasoning he deduces the conclusion that *induction* and *conduction* not only depend essentially on the same principles, but that they may be regarded as being of the same nature, and as differing merely in degree.

The fact ascertained by Professor Wheatstone, that electric conduction, even in the most perfect conductors, as the metals, requires for its completion a certain appreciable time, is adduced in corroboration of these views; for any retardation, however small, in the transmission of electric forces can result only from induction; the degree of retardation, and, of course, the time employed, being proportional to the capacity of the particles of the conducting body for retaining a given intensity of inductive charge. The more perfect insulators, as lac, glass and sulphur, are capable of retaining electricity of high intensity; while, on the contrary, the metals and other excellent conductors, possess no power of retention when the intensity of the charge exceeds the lowest degrees. It would appear, however, that gases possess a power of perfect insulation, and that the effects generally referred to their capacity of conduction, are only the results of the carrying power of the charged particles either of the gas, or of minute particles of dust which may be present in them: and they perhaps owe their character of perfect insulators to their peculiar physical state, and to the condition of separation under which their particles are placed. The changes produced by heat on the conducting power of different bodies is not uniform; for in some, as sulphuret of silver and fluoride of lead, it is increased; while in others, as in the metals and the gases, it is diminished by an augmentation of temperature.

One peculiar form of electric discharge is that which attends *electrolyzation*, an effect involving previous induction; which induction has been shown to take place throughout linear series of polarized particles, in perfect accordance with the views entertained by the author of the general theory of inductive action. The peculiar feature of this mode of discharge, however, is in its consisting, not in a mere interchange of electric forces at the adjacent poles of contiguous particles, but in their actual separation into their two constituent particles; those of each kind travelling onwards in contrary directions, and retaining the whole amount of the force they had ac-

quired during the previous polarization. The lines of inductive action which occur in fluid electrolytes are exemplified by employing for that purpose clean rectified oil of turpentine, containing a few minute fibres of very clean dry white silk; for when the voltaic circuit is made by the introduction into the fluid of wires, passing through glass tubes, the particles of silk are seen to gather together from all parts, and to form bands of considerable tenacity, extending between the ends of the wires, and presenting a striking analogy to the arrangement and adhesion of the particles of iron filings between the poles of a horse-shoe magnet.

The fact that water acquires greater power of electrolytic induction by the addition of sulphuric acid, which not being itself decomposed, can act only by giving increased facility of conduction, is adduced as confirming the views of the author.

The phenomena of the disruptive electric discharge are next examined with reference to this theory: the series of inductive actions which invariably precede it are minutely investigated: and reference is made to the accurate results obtained by Mr. Harris, as to the law of relation between the intensity of a charge, and the distance at which a discharge takes place through the air.

The theory of Biot and others, which ascribes the retention of a charge of electricity in an insulated body to the pressure of the surrounding atmosphere, is shown to be inconsistent with various phenomena, which are readily explained by the theory adopted by the author.

The author then enters into an inquiry relative to the specific conducting capacities of different dielectrics.

With a view of determining the degrees of resistance to the transit of electricity excited by different kinds of gases, he constructed an apparatus, in which an electric discharge could be made along either of two separate channels; the one passing through a receiver filled with the gas, which was to be the subject of experiment, and the other having atmospheric air interposed. By varying the length of the passage through the latter, until it was found that the discharge occurred with equal facility through either channel, a measure was afforded of the relative resistances in those two lines of transit, and a determination consequently obtained of the specific insulating power of the gas employed.

The circumstances attending the diversified forms of the disruptive discharge, such as the vivid flash or spark, the brush or pencil of light, and the lucid point or star, which severally represent different conditions of the sudden transit of electrical forces through an intervening dielectric, are minutely investigated in their various modifications. The spark is the discharge, or reduction of the polarized inductive state of many dielectric particles, by the particular action of a few of those particles occupying but a small and limited space, leaving the others to return to their original or normal condition in the inverse order in which they had become polarized: and its path is determined by the superior tension which certain particles have acquired, compared with others, and along which the action is accord-

ingly conducted in preference to other lines of transit. The variety in the appearance of the electric spark taken in different gases may be ascribed partly to different degrees of heat evolved, but chiefly to specific properties of the gas itself with relation to the electric forces. These properties appear also to give occasion to diversities in the form of the pencil or brush, which takes place when the discharge is incomplete, and is repeated at short intervals, according to the shape of the conductor on either side, and according to the species of electricity conveyed. The diverging, converging, bent and ramified lines presented in these different forms of electric discharge, strikingly illustrate the deflexions and curvilinear courses taken by the inductive actions which precede the disruption; these lines being not unlike the magnetic curves in which iron filings arrange themselves when under the action of opposite magnetic polarities.

March 8, 1838.

FRANCIS BAILY, Esq., V.P. and Treas., in the Chair.

Colonel Andrew Leith Hay, K.H., who had at the last Anniversary ceased to be a Fellow from the non-payment of his annual contribution, was at this meeting re-elected by ballot into the Society.

A paper was read, entitled, "Proposal for a new method of determining the Longitude, by an absolute Altitude of the Moon," by John Christian Bowring, Esq. Communicated by John George Children, Esq., F.R.S.

The method employed by the author for determining the longitude by the observation of an absolute altitude of the moon, was proposed, many years ago by Pingré and Lemmonier; and the principal difficulty which stood in the way of its adoption, was its requiring the exact determination of the moon's declination reduced to the place of observation. This difficulty the author professes to have removed by supposing two meridians for which the altitudes are to be calculated: and the only remaining requisite is the accurate determination of the latitude, which presents no great difficulty, either on land or at sea. Examples are given of the practical working of this method; showing that if the latitude of a place of observation be obtained within a few seconds, the longitude will be found by means of a single observation of the altitude of the moon.

A paper was also read, entitled, "An Inquiry into a new Theory of earthy Bases of Vegetable Tissues," by the Rev. J. B. Reade, M.A., F.R.S.

The author, after briefly noticing the results of some of his experiments described in two papers which appeared in the Philosophical Magazine for July and November, 1837, and also those of Mr. Robert Rigg in a paper read to the Royal Society, next adverts to the theory of M. Raspail, detailed in his *Tableau Synoptique*, and *Nouveau Système de Chimie*. In opposition to some of the views enter-

tained by the latter, he finds that in the bark of the bamboo and the epidermis of straw the silica incrusting these tissues is not crystallized, but, on the contrary, exhibits, both before and after incineration, the most beautiful and elaborate organization, consisting of an arranged series of cells and tubes, and differing in its character in different species of the same tribe, and in different parts of the same plant.

The observations of Mr. Golding Bird, contained in the 14th number of the Magazine of Natural History, New Series, are then referred to; and the author states in confirmation, that, by employing caustic potash, the siliceous columns may be removed from the leaf of a stalk of wheat, while the spiral vessels and ducts, which form the principal ribs of the leaf, as well as the apparently metallic cups which are arranged on its surface, remain undisturbed. He proposes, therefore, to substitute, in the description of vegetable tissues, the term *skeleton*, instead of that of *bases*, whether saline or siliceous, of those tissues.

March 15, 1838.

FRANCIS BAILY, Esq., V.P. and Treas., in the Chair.

Captain Thomas Best Jervis, E.I.C.S., and Travers Twiss, Esq., were elected Fellows of the Society.

The reading of a paper, entitled, "Experimental Researches in Electricity," Thirteenth Series, by Michael Faraday, Esq., D.C.L., F.R.S., &c., was commenced.

March 22, 1838.

FRANCIS BAILY, Esq., V.P. and Treas., in the Chair.

A paper was read, entitled, "Description of a new Tide-Gauge, constructed by T. G. Bunt, and erected on the Eastern bank of the River Avon, in front of the Hotwell House, Bristol, in 1837." Communicated by the Rev. William Whewell, M.A., F.R.S.

The principal parts of the machine here described, are an eight-day clock, which turns a vertical cylinder, revolving once in twenty-four hours; a wheel, to which an alternate motion is communicated by a float rising and falling with the tide, and connected by a wire with the wheel which is kept constantly strained by a counterpoise; and a small drum on the same axis with the wheel, which by a suspending wire communicates one 18th of the vertical motion of the float to a bar carrying a pencil which marks a curve on the cylinder, or on a sheet of paper wrapped round it, exhibiting the rise and fall of the tide at each moment of time. The details of the mechanism, illustrated by drawings, occupy the whole of this paper.

A paper was also read, entitled, "On the Régar or Black Cotton Soil of India," by Capt. Newbold, Aide-de-Camp to Brigadier-Ge-

neral Wilson. Communicated by S. H. Christie, Esq., M.A., Sec. R.S.

The author states that the Régar of India is found, by chemical analysis, to consist of silica, in a minute state of division, together with lime, alumina, oxide of iron, and minute portions of vegetable and animal *débris*. Hence it is usually considered as having been formed by the disintegration of trap rocks: the author, however, after examining its numerous trap dykes traversing the formation of the ceded districts, which he found invariably to decompose into a ferruginous red soil, perfectly distinct from the stratum of black régar through which the trap protrudes, was led to regard this opinion of its origin as erroneous: and from the circumstance of its forming an extensive stratum of soil covering a large portion of the peninsula of India, he believes it to be a sedimentary deposit from waters in a state of repose.

Specimens of basaltic trap and of the Régar soil were transmitted to the Society by the author, for the purpose of analysis.

The reading of a paper, entitled, "Experimental Researches in Electricity," Thirteenth Series, by Michael Faraday, Esq., D.C.L., F.R.S., &c., was resumed but not concluded.

March 29, 1838.

JOHN GEORGE CHILDREN, Esq., V.P., in the Chair.

Simon MacGillivray, Esq., was elected a Fellow of the Society.

The reading of a paper, entitled, "Experimental Researches in Electricity," Thirteenth Series, by Michael Faraday, Esq., D.C.L., F.R.S., was resumed but not concluded.

April 5, 1838.

FRANCIS BAILY, Esq., V.P. and Treas., in the Chair.

John Hardwick, John Macneill, and Edward William Tuson, Esqs., were elected Fellows of the Society.

The reading of a paper, entitled, "Experimental Researches in Electricity," Thirteenth Series, by Michael Faraday, Esq., D.C.L., F.R.S., was resumed and concluded.

The author, in this paper, pursues the inquiry into the general differences observable in the luminous phenomena of the electric discharge, according as they proceed from bodies in the positive or the negative states, with a view to discover the cause of those differences. For the convenience of description he employs the term *inductric*, to designate those bodies from which the induction originates, and *inducteous* to denote those whose electric state is disturbed by this inductive action. He finds that an electric spark, passing from a small ball, rendered positively *inducteous*, to another ball of larger diameter, is considerably longer than when the same

ball is rendered positively *inductric*; and that a similar difference, though to a less extent, is observable, when the smaller ball is rendered negative. The smaller ball, rendered positive, gives also a much longer spark than when it is rendered negative; in which latter case, however, it affords, at equal distances, a luminous brush of greater size, and gives it much more readily than when positive. In order to ascertain the relative degrees of charge which the balls acquire before the occurrence of the discharge, the author employed an apparatus attached to the insulated conductor of the electrical machine, and also to the conductor connected with the discharging train, and consequently uninsulated, consisting, on each side, of a rod branching out in the form of a fork, and terminating, at one of its extremities in a large ball, and at the other in a small one; the position of the forks being capable of adjustment, so that the large ball of each rod might be brought exactly opposite to the small one of the other: and the distances between each pair admitted of being regulated at pleasure, until the discharges through each interval were rendered apparently equal to one another. From numerous experiments made with this instrument, the author concludes that when two conducting surfaces of small but equal size, are placed in air, and electrified, the one positively and the other negatively, a discharge takes place at a lower tension from the latter than from the former; but that, when a discharge does occur, a greater quantity of electricity passes at each discharge from the positive, than from the negative surface. Experiments of a similar nature were made in gases of different kinds, by enclosing them in an apparatus constructed on the same plan as the former one, but capable of acting in a receiver, from which the air could be exhausted, and the particular gas, whose powers in modifying the electric discharges were to be ascertained, could be introduced in its place. The results of various trials are given in a table, from which it appears that different gases restrain the discharge in very different degrees. The discharge from the small ball, through nitrogen and hydrogen gases, most readily takes place when the charge is positive; and through oxygen, carbonic acid, and coal gas, when it is negative.

The author next directs his attention to the peculiar luminous phenomena attending the disruptive electrical discharge, which he terms *a glow*, and which appears to depend on a quick, and almost instantaneous charge given to the air in the immediate vicinity, and in contact with the charged conductor; and he enters into a detailed account of the circumstances by which it is influenced, and its production favoured; such as diminution of the charging surface, increase in the power of the machine, rarefaction of the surrounding air, and the particular species of electricity concerned. The relations which the glow, the brush, and the spark bear to one another, as well as the steps of transition between each are minutely investigated; and the conclusion is deduced that the glow is in its nature exactly the same as the luminous part of a brush or ramification, namely, a charge of air; the only difference being that the glow has a continuous appearance from the constant renewal of the same action in the same place, whereas the ramification is occa-

sioned by a momentary and independent action of the same kind. The disruptive discharge may take place at degrees of tension so low as not to give rise to any luminous appearance; so that a dark space may intervene in the line of actual discharge, as is frequently observable between the brush on one side, and the glow on the other. Thus it is inferred that electric light is merely a consequence of the quantity of electricity which, after a discharge has commenced, flows and converges towards the spot where it finds the readiest passage: and these conclusions are further confirmed by the phenomena which take place in other gases, besides atmospheric air, and which are specifically detailed by the author.

The last kind of discharge which is here considered is the *convective* or *carrying discharge*, namely, that effected by the translation of charged particles from one place to another. The phenomena attending this mode of transference are examined under various aspects as they occur in air, in liquids of various kinds, in flame, and as they are exhibited in the case of particles of dust, which perform the office of carriers of the electricity; and also in that of solids terminated by liquids. Thus all these apparently isolated phenomena comprised under the heads of the electric currents which characterize electrolyzation, of transference through dielectrics by disruptive discharges of various kinds, or by the actual motion of charged particles, and of conduction through conductors of various degrees of power, are assimilated to one another by their being shown to be essentially the result of actions of contiguous particles of matter assuming particular states of polarization.

The author lastly considers electric currents, not only in their effects on the bodies they traverse, but also in their collateral influences as producing inductive and magnetic phenomena. The analogies, which connect electrolytic discharge with that by conduction, are pointed out, as tending to show that they are essentially the same in kind, and that when producing different kinds of motion in the particles of matter, their mode of operation may be regarded as identical. An attempt is made to connect with these views the lateral or transverse actions of currents, which are most distinctly manifested in their magnetic effects; these effects being produced equally by the disruptive, the conductive, and the electrolytic discharges, and probably depending on the transverse condition of the lines of ordinary induction. This transverse power has the character of polarity impressed upon it, and, in its simplest form, appears as attractive or repulsive, according as the currents themselves are in the same, or in opposite directions. In the current and in the magnet it assumes the condition of tangential force; and in magnets and their particles it produces poles.

The author announces that he intends shortly to develop, in another series of these researches, some further views which he entertains concerning the nature of electric forces and electric excitation in connexion with the theory he has here advanced.

The Society then adjourned over the Easter Recess to meet again on the 26th instant.